



A Novel Integrated Point Detection Based Feature Extraction Technique for Early Diagnosis of Alzheimer's Disease from MRI Brain Images

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ABSTRACT

Background: Nowadays, the number of people diagnosed with Alzheimer's disease is increasing rapidly due to lifestyle changes. The average age of Alzheimer's patients is now in the range of 65-80 which was earlier of 75 and above. It has always been challenging to the doctors for proper diagnosis and planning of appropriate treatment of this disease. The manual identification of Alzheimer's disease from MRI images is influenced by different factors and may vary from experts depending on their expertise in the diagnosis of the disease. There is no efficient technique so far for the accurate diagnosis of Alzheimer's disease at the very early stage to prevent the progress of the disease.

Objectives: The main aim of the study is to develop an algorithm which could detect the presence of Alzheimer's disease from the brain MRI images by extracting the brain features so that the presence of Alzheimer's disease can be detected at the initial stage itself and appropriate treatment could be given at the right time to prevent its progression.

Methods: About 6000 MRI brain images which are used for the study is obtained from ADNI Database. The MATLAB toolbox is used for design and programming. A new algorithm is developed using combined feature extraction using SURF, FAST, BRISK, Harris and Min Eigen methods followed by HOG and feature selection using Principal Component Analysis method for early prediction of various stages of Alzheimer's disease. An analysis of the proposed method is done by combining it with k Nearest Neighbor, Decision Tree and Naïve Bayes and Random Forests classifiers and the performance parameters are evaluated.

Results: The accuracy of 98.3% is obtained when K-nearest Neighbor is used for classification of Alzheimer's disease. This is followed by Decision Tree having an accuracy of 98.13%, Naïve Bayes with an accuracy of 97.31% and Random Forests having an accuracy of 97.12%.

Conclusion: The proposed algorithm is found to be superior to the methods which use only one feature extraction method which is developed for the prediction and classification of Alzheimer's disease.

Key Words: Alzheimer's disease, Feature Extraction, Feature Selection, Mild Cognitive Impairment, k Nearest Neighbor, Decision Tree, Naïve Bayes, Random Forests

INTRODUCTION

Alzheimer's disease is an irrevocable brain disease that steadily destroys brain cells and hence resulting in permanent memory losses over time. The possibility to regain a person's condition who is suffering from Alzheimer's disease (AD) mainly depends on its identification and diagnosis. The choice of the treatment of AD is determined by the identification of various stages of AD. Specialist doctors use various biomarkers for the spotting of AD. The different biomarkers like Cerebrospinal fluid biomarker in Magnetic Resonance Imaging (MRI) brain images were utilized to de-

tect Alzheimer's disease and to track the progression of the disease¹. Here variations in the level of biomarkers are used for the diagnosis of AD. A set of serum markers have been discovered which may occur due to inflammatory actions in the central nervous system during the early course of AD. This technique is the most acceptable method to diagnose AD with high specificity and sensitivity. But Biomarkers are not useful for early diagnosis of the disease. Moreover, it must use an intracerebral ventricular injection. To collect the CSF the clinical employees must take utmost care without damage brain tissues and spinal cord. This is one among the foremost important mechanism to estimate the Alzheimer's

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where they estimate the tangle and plaque of the brain tissues for Alzheimer's analysis.

Recently volumetric methods have been used for analyzing the results manually or by partial automatic means by using SPM-5 in MATLAB Environment². There the neurologist needs to calculate the total volume of the different regions such as white matter, grey matter, CSF and sum together conclude the stage of the disease³. In this work, a new machine learning method is developed to find the presence of Alzheimer's disease at a very early stage using combined Point Detection and Feature Extraction methods.

FEATURE EXTRACTION METHODS

The different feature extraction methods used in the proposed method are SURF, BRISK, FAST, Harris, and MinEigen.

SURF (Speeded Up Robust Features)

The SURF uses the same principle as that of the SIFT (Scale Invariant Feature Transform) algorithm. In this method, the image is converted into its corresponding coordinates with the multi-resolution pyramid technique. The so obtained Laplacian Pyramid-shaped original image is then copied to and an image having the same size and reduced bandwidth image is obtained⁴. This makes the original image blurred and is known as Scale-Space. It also fortifies that points of interest are also scale-invariant.

FAST (Features from accelerated segment test)

FAST program is mainly used for corner detection. It is based on summing the differences between the pixels. This method reads the first frame and converts it to a gray scale and retrieves a vector of corner locations⁵. To display the corner locations, this vector is used to draw bright green dots over the corner pixels in the output frame.

BRISK (Binary Robust Invariant Scalable Key-points)

The BRISK attains scale of a key point from the BRISK detector⁶. The FAST score in the scale-space pyramid is computed by the BRISK detector and then it will select the scale which has a high score.

Harris

The Harris feature detector is also used for corner detection. It consists of two steps:

- 1) Discovering Harris corners using the Harris affine detection on nine pre-selected scales and two additional scales surrounding the most populated one.
- 2) Culling weak points using a measure derived from the Hessian determinant⁷.

MinEigen

The MinEigen algorithm uses minimum Eigen value metric which contains the information about the corner locations.

HOG (Histogram of Oriented Gradients)

This feature extraction technique counts the number of occurrences of the orientation of gradients in the localized areas of an image⁸.

Table 1 shows the number of feature points detected and matched using the combined feature extraction method.

Table 1: Detected Feature Points

Feature Detection Method	Matched Features
SURF	200
FAST	258
BRISK	220
Harris	283
MinEigen	532

FEATURE SELECTION METHOD

The feature selection is used to enhance the efficiency of the machine learning classifiers by selecting the relevant features. The PCA (Principal Component Analysis) feature selection is used in the proposed method.

The PCA is an unsupervised machine learning technique⁹. It uses a statistical method which uses an orthogonal transformation that will transform a list of correlated variables to a list of uncorrelated variables. PCA is a popular tool in exploratory data analysis and machine learning for predictive neural network models. It is used to analyze the interrelations between the variables.

CLASSIFICATION ALGORITHMS

Different powerful machine learning algorithms that extract different features from MRI images for the detection of Alzheimer disease have been developed by Scientists. In this paper, various classification algorithms like k Nearest Neighbor, Decision Tree, Random Forest, Naive Bayes are incorporated along with the proposed method and each of their performance is compared and analyzed.

k Nearest Neighbor

In k-Nearest Neighbor classifier, the nearest neighbours of an instance are specified in terms of Euclidean distance in which all samples match the points in the n-dimensional space R_n [10]. Euclidean distance between the samples

$$X_i = \langle X_{i1}, X_{in} \rangle \&$$

$$X_j = \langle X_{j1}, X_{jn} \rangle \text{ is stated as}$$

$$X_i - X_j = r = \ln(X_i + X_j)^2 \quad (1)$$

Decision Tree

The Decision Tree is a symbolic illustration of a tree in which the nodes of the tree depict decisions and the branches represent possible routes in between the nodes¹¹. A decision tree is mainly used for classification purpose, it clutches with a set of attributes and begins at the root, and then iterate through each following decision node and approach the terminal node.

Random Forest

In Random forest, the prediction model operates by selecting N random data from the dataset and creating a decision tree from these N records¹². This is accompanied by selecting the count of trees used in this method and then these steps are repeated. In the regression problem, each tree in the forest estimates a value for the output for new data. The average of all the values estimated by all the trees in the forest determines the final value.

In a classification problem, each tree in the forest predicts the class for new data¹³. Then the new data is assigned to that class that has the majority nomination.

Naive Bayes

Naive Bayes classifier operates on the Bayes probability model. The naive Bayes classifier integrates the Bayes probability model and a decision rule¹⁴. A Bayes classifier delegate a class label $y =$ for some values of having values ranging from 1,2,3....K.

$$P(C_k) = \prod_{i=1}^n P(x_i | C_k) \quad (2)$$

PROPOSED COMBINED POINT DETECTION FEATURE EXTRACTION METHOD

In this work, a new technique is proposed for the detection of Alzheimer's disease at a very early stage using combined point detection feature extraction methods. This new method provides a higher accuracy rate and fast computation rate when compared to the existing methods.

The MATLAB toolbox is used for design and programming. The MRI brain images which are used for the study is obtained from ADNI (Alzheimer's disease Neuroimaging Initiative) Database. The feature selection is used to enhance the efficiency of the machine learning classifiers by selecting the relevant features. The PCA (Principal Component Analysis) feature selection is used in the proposed method. The entire workflow of the proposed method is shown in Figure 1.

The MRI affected, and suspected brain images are pre-processed for enhancement of the images¹⁴. Here Wiener filtering technique is used for noise removal in MRI brain images. An affine transformation is used to maintain appropriate angles connecting lines or to maintain appropriate distances between

points and to maintain appropriate ratios of distances connecting points on a straight line. The preprocessing is followed by different Feature Extraction methods like SURF, BRISK, FAST, Harris and MinEigen followed by HOG which extracts different point, shapes and Texture features. The features of the trained images are also extracted by the above method for comparing.

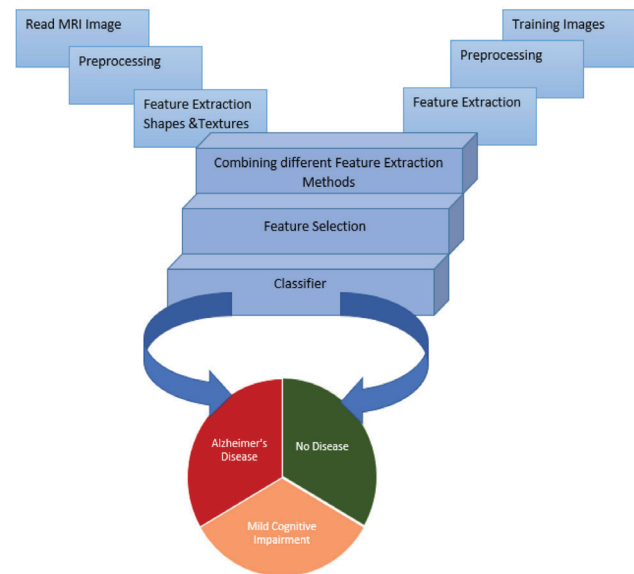


Figure 1: The workflow of the proposed method.

The different features obtained from the SURF, BRISK, FAST, Harris and Min Eigen algorithms are combined, and the strongest points are obtained to get the adequate number of features^{15,16}. The Principal Component Analysis method is used for Feature Selection. Finally, the images are sent to different classifiers for classification of different stages of Alzheimer's disease.

PERFORMANCE ANALYSIS PARAMETERS

In this work, three classes are separated for the analysis and the performance of the proposed method is evaluated based on four parameters such as True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) which are obtained from the AD, MCI and No Diseased images present in the datasets¹⁷. The Classification Accuracy, Sensitivity, Specificity and Time Consumption is calculated using the values of TP, TN, FP and FN.

Classification Accuracy

The proximity of a measured or actual value to the expected value is known as classification accuracy.

$$\text{Classification Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (3)$$

Sensitivity

Sensitivity is the proximity of patients with Alzheimer's disease who test positive.

$$\text{Sensitivity} = \text{TP} \div (\text{TP} + \text{FN}) \quad (4)$$

Specificity

Specificity is the proximity of patients without Alzheimer's disease who test negative.

$$\text{Specificity} = \text{TN} \div (\text{TN} + \text{FP}) \quad (5)$$

Time Consumption

Time taken to obtain the analysis result is termed as time consumption and it is available from MATLAB results viewer and it is measured in Seconds.

RESULTS

The parameters such as True Positive, True Negative, False Positive, and False Negative which are obtained from the AD, MCI and No Diseased MRI images are determined to calculate the performance metrics such as classification accuracy, sensitivity, specificity and time consumption. Table 2 shows the measurements of the parameters from the output of different classifiers used in the new proposed prediction model.

Table 2: Parameters measurements of different classifiers

Classifiers	Number of Samples	Accuracy	Sensitivity	Specificity	Execution Time (Seconds)
k Nearest Neighbor	50	96.43	0.69	0.14	0.44
	75	97.70	0.76	0.17	0.57
	100	98.3	0.83	0.29	0.63
Decision Tree	50	94.53	0.62	0.09	0.53
	75	97.40	0.73	0.14	0.69
	100	98.13	0.84	0.22	0.78
Naive Bayes	50	95.42	0.63	0.12	0.57
	75	96.11	0.69	0.15	0.72
	100	97.31	0.81	0.20	0.83
Random Forest	50	94.36	0.62	0.13	0.41
	75	95.63	0.72	0.15	0.48
	100	97.12	0.85	0.23	0.56

The Receiver Operating Characteristic curves (ROC) are obtained for the proposed combined feature extraction method using different neural network classifiers such as k NN, Decision Tree, Random Forests and Naïve Bayes and the area under the curve of each of the classification prediction model has been analyzed.

The performance of the new proposed prediction model using different operating classifiers is shown by the ROC Curve in Figure 2.

DISCUSSIONS

The input images used for this research is obtained from the Alzheimer's Disease Neuroimaging Initiative (ADNI) database that consists of 100 samples those between ages 18 to 87. The performance metrics such as classification accuracy, sensitivity, specificity and time consumption are calculated for different classifiers using the new prediction model. From the analysis of the investigation results of different classifiers in the new prediction model, it was seen that the accuracy of classification is found to be high when k Nearest Neighbor classifier is integrated with the new proposed combined feature extraction method when compared

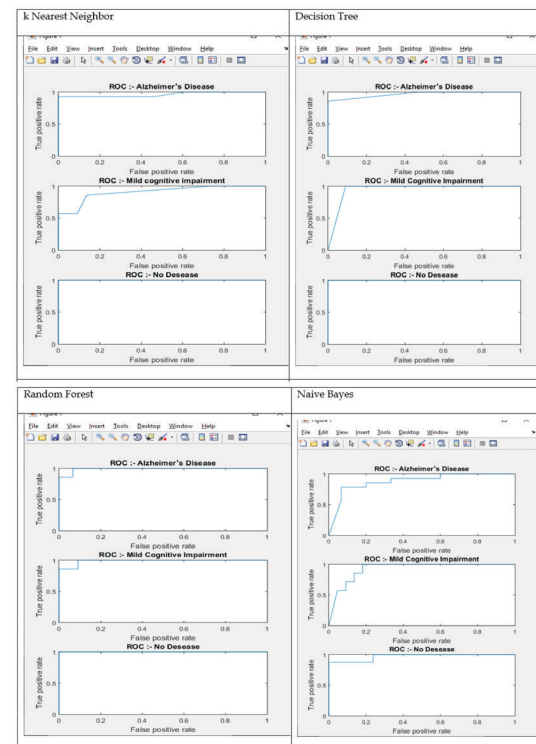


Figure 2: ROC Curve of performance of the different operating classifiers.

to other classifiers which are used for integration. The k-NN is followed by Decision Tree, Naive Bayes and Random Forest classifiers in accuracy measurements in the new method. And the execution time is found to be low when Random Forest classifier is used.

The following are the advantages of the new proposed prediction model.

1. High Accuracy Rate
2. High Sensitivity
3. High Specificity
4. Less Time Consumption

From these features, the new method is found to be superior to the existing methods. Moreover, it has the advantage of combined multiple points based feature extraction methods and hence the accuracy rate is very high and so it can be used with any classifiers to yield high accuracy rates for classification purposes.

The ROC curves are used to assess the performance of the classifier over its complete operating range. The AUC (Area Under Curve) is used to compare the performance of k-Nearest Neighbor, Decision Tree, Naive Bayes and Random Forest classifiers after integrating the feature extraction methods by the proposed method. The AOC of all the ROC's is high when the new proposed feature algorithm is used in different classifiers. The ROC Curve implies that the new proposed model works with high efficiency in the early prediction and classification of various stages of Alzheimer's disease.

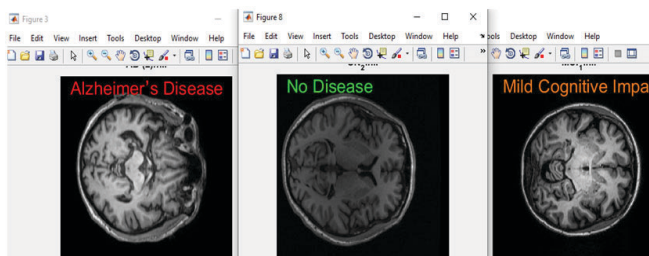


Figure 3: Classification outcome - Alzheimer's disease, No Disease, Mild Cognitive Impairment.

The classification outcomes are shown in Figure 3. From the investigation of results, it implies that the new proposed prediction model is a propitious solution in the healthcare domain in the early prediction and classification of various stages of Alzheimer's disease.

CONCLUSION

In the study, a new method is proposed for early prediction of Alzheimer's disease using combined point detection and feature extraction methods. The different feature extraction methods such as SURF, FAST, BRISK, Harris and

Min Eigen methods are combined followed by extraction of HOG features from the match points and feature selection is carried out using Principal Component Analysis method. The proposed algorithm is integrated with different neural network classifiers like k Nearest Neighbor, Decision Tree, Naive Bayes and Random Forests and the efficiency of each classifier is evaluated. The performance metrics and ROC curves are obtained for each method. The implementation results have been analyzed and compared in terms of classification accuracy, sensitivity, specificity and time consumption. The area under curve of all the classifier's ROC's is high when the new proposed feature algorithm is incorporated in different classifiers. From the study, the classification accuracy is found to be high for k NN classifier and is followed by Decision Tree and Naïve Bayes classifier when the new feature extraction method is used. The accuracy of 98.3% is obtained when k-NN is used for classification of Alzheimer's disease. This is followed by Decision Tree having an accuracy of 98.13%, Naive Bayes with an accuracy of 97.31% and Random Forests having an accuracy of 97.12%. The execution time is found to be low when Random Forest classifier is used. These results and the findings recommend that this new proposed approach is efficient and will be promising for clinical applications.

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